Flow Visualization and Processes Laboratory
Vadose Zone Research and Development Facilities

Need

Much of the present interest in vadose zone hydrology in arid climates is due to evidence that even thick vadose zones have limited ability to buffer against contaminant transport to the saturated zone. Removing contaminants from the vadose zone is a logical approach to preserving the quality, and therefore, the quantity of groundwater resources. However, our present understanding of vadose zone flow and transport processes limits the effectiveness of such remediation schemes. Mantoglou and Gelhar (1987) underscore the state of knowledge concerning vadose zone flow field behavior by remarking that, "Unsaturated flow in natural soils is such a highly complex process that even the most basic system behavior is presently not very well understood." Improved field-scale understanding of complex vadose zone processes is very important to furure characterization and remediation of vadose zone contamination.

Description

One approach to better understand basic vadose zone flow and transport processes is to conduct large-scale field experiments where natural hydrologic systems are stressed through controlled infiltration events while dense arrays of instruments monitor essential hydrologic state variables (i.e., formation water content, pressure potential, and temperature). Although field experiments of this type are not frequently performed, they provide major opportunities to advance understanding of vadose zone flow and transport processes. For example, flow and transport mechanisms can be ascertained, spatial variability of hydraulic properties can be characterized and related to flow field behavior, and physically based models can be tested against vadose zone response to known boundary conditions.

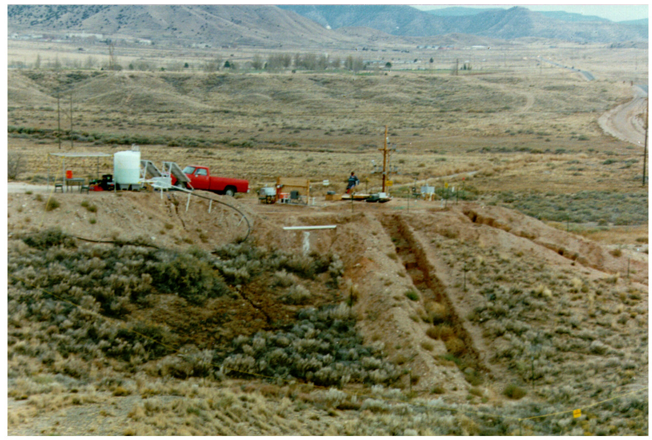
Vadose Zone Research Facilities

In the tectonic basins of the western United States, vadose zones typically consist of thick sequences of basin fill deposits. In many basins, thick sequences of alluvial fan sediments derived from adjacent uplifted terrain and fluvial sediments deposited by through-flowing rivers comprise a large percentage of basin fill materials. Sharp contrasts in texture and hydraulic properties within these deposits result in complicated unsaturated flow and transport behavior. Additionally, alluvial fan and fluvial deposits contrast in texture, depositional structure, and rock mineralogy to the extent that crucial differences in flow and transport processes can be expected in these deposits.

In an effort to better understand these processes, as well as to evaluate existing and new measurement techniques, two infiltration facilities have been constructed in the north-south-trending Rio Grande rift in New Mexico: the Tijeras Arroyo Vadose Zone Facility (TAVZ) and the Sandia-Tech Vadose Zone Facility (STVZ). The TAVZ is located on alluvial fan deposits in the Albuquerque basin, while the STVZ is located on ancestral Rio Grande alluvial depostis in the Socorro Basin. Both facilities are designed to provide quantitative data elucidating the response within naturally occurring heterogeneous vadose zone materials to regulated intrusion of fluids. This is accomplished through extensive use of automated data acquisition systems that monitor dense arrays of multiplexed subsurface probes with high temporal resolution. Theautomated measurement capabilities at both sites include water content, pressure potential, and temperature. In addition, installed a the STVZ site are arrays of electrical probes for measurement of 3-dimensional-resistivity fields through application of electric resistive tomography (ERT) techniques.

The Tijeras Arroyo Vadose Zone Facility

The TAVZ is located south of Albuquerque, New Mexico on Kirtland Air Force Base at the end of a ridge extending from the north escarpment of Tijeras Arroyo. This site was chosen for several reasons. The deposits exhibit sharp contrasts in textures typical of alluvial fan deposits found in tectonic basins throughout the western United States. These deposits contain textural heterogeneities ranging from small scale sedimentary structures to larger scale layers comprised of contrasting fine and coarse-grained sediments. Pedogenic horizons are also observed at the TAVZ site. The site is located on the end of a ridge providing the ability to develop a three-dimensional geologic map of the materials to be infiltrated. Well-exposed continuous outcrops in the vicinity provide ample opportunity to collect geostatistical data which may be integrated with the results of the infiltration test to determine expected variations and trends of hydraulic properties.



View of the TAVZ to the northeast. The infiltration site is shown with the infiltrometer (covered with plywood deck) in the center of the instrument arrays. The data acquisition systems are located to the left beyond the instrument arrays. Beyond the data acquisition systems are photovoltaic systems required for power at the site and water supply tanks. Neutron probe readings are in process.

Characterization activities at the site have included identification and mapping of distinct geologic units in nearby trenches, construction of geologic cross-sections by correlating information between nearby trenches and continuous core samples taken from vertical bore holes augered for instrumentation. In addition, hydraulic properties (saturated hydraulic conductivity and pressure-saturation curves) from samples collected from each of the geologic units have also been measured.

Instruments installed at the site consist of 36 surface and 48 subsurface time domain reflectometry (TDR) probes, with attached thermocouples, 96 pressure transducer equipped tensiometers paired with the 48 subsurface TDR probes, 16 pressure transducer equipped “geology” tensiometers installed in specific geologic units, and 13 neutron access tubes. The probes were installed in a staggered axisymmetric pattern that allows for identification of nonsymmetric flow fields. Evaporation from the subsurface and infiltration from precipitation is prevented by a vapor barrier consisting polyurethane tarps covered with 0.3 meters of dirt from the site.

Research activities to date include the implementation of a ponded infiltration event lasting 26 days with continued monitoring during redistribution and an extensive evaluation of measurement errors from data collected during infiltration and redistribution.

The Sandia-Tech Vadose Zone Facility

The STVZ is located adjacent to the New Mexico Institute of Mining Technology (New Mexico Tech) campus in Socorro, New Mexico on a small southeast trending ridge bounded by drainages to the north and the south. This site was chosen because the deposits exhibit contrasting textures and fluvial depositional features typical of similar deposits found in the Rio Grande rift as well as other river basins in the west. These deposits consist of highly permeable ancestral Rio Grande sands and gravels exhibiting layering and cross bedding. The site also contains beds of clayey silt. The site is located on a ridge providing the ability to collect extensive geostatistical data from the sides of the ridge and from a nearby sandpit. Because the site is adjacent to the New Mexico Tech campus, it will serve as a long-term research and teaching facility.

Geophysical characterization has included electrical conductivity induction (ECI) logging, cross-hole ground penetrating radar (GPR), and ERT logging. Geologic characterization activities at the site have included identification and mapping of distinct geologic units through continuous core samples obtained from drilling. The ECI and GPR data have provided additional information on the location and extent of the geologic units. Hydrologic characterization has included measurement of saturated hydraulic conductivity, pressure-saturation curves, and saturation-electrical resistivity measurements from samples collected during drilling and in a trench excavated into a hill slope adjacent to, and below the site. In the future, the hill slope will be excavated to provide exposures for collecting intact samples to be used for obtaining additional hydrologic and geophysical properties and to provide the opportunity to characterize heterogeneities within the deposits. Infiltration will be initiated after all systems are thoroughly tested and data processing programs are fully operational. Unsaturated conditions will be maintained by infiltrating at a rate less than the saturated hydraulic conductivity.

View of the STVZ looking to the north. Photo was taken before the site was fully constructed. The instrument pad is visible in the foreground with the infiltrometer (covered with a blue tarp) located in the center of the instrument arrays. All the data acquisition systems and water supply equipment are located in the insulated building located behind and to the right of instrument pad.

The STVZ contains a data acquisition building located in the northern part of a 900-square meter leveled area. All instrumentation is located within a 15 by 15 meter area that was leveled without disturbing subsurface materials. The site is located on a ridge bounded by a sand pit to the west, a 20 degree slope immediately to the south of the instrument pad, and more gentle slopes to the east and north east. An infiltration system, located at the center of the instrumented site, produces a constant flux boundary condition across a 3 x 3 meter infiltration pad.

The instrumented site contains 13 wells cased with PVC to a depth of 12 meters to provide subsurface access for neutron probe (for measuring water contents), ECI, and GPR probes, 80 pressure transducer equipped tensiometers, 20 suction lysimeters, and 20 TDR probes. The site also contains eight vertically installed ERT electrode strings and a grid of surface electrodes. Each ERT string contains 17 electrodes ranging in depth from the surface to a depth of 12m depth. Evaporation from the subsurface and infiltration due to precipitation are prevented by a vapor barrier consisting of a polyurethane ground tarp covered with 0.30 meters of sand from the site.

Current Research Focus

Current research at these field test sites is focused on the development of a hybrid hydrologic-geophysical inverse technique. This technique combines information from electrical resistance tomography (ERT), statistical information about site geology, and sparge data on moisture and contaminant distributions to provide improved estimates of hydraulic properties and three-dimensional contaminant distributions. This research activity is funded by the DOE Environmental Science Management Program (EMSP).

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